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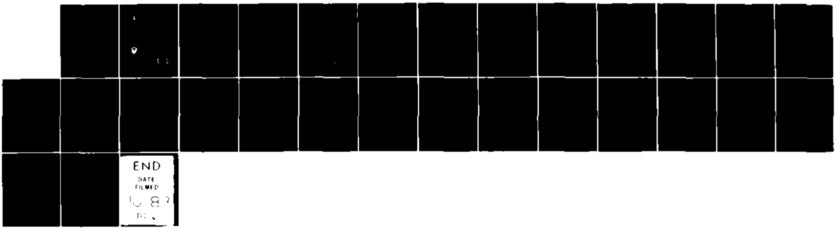

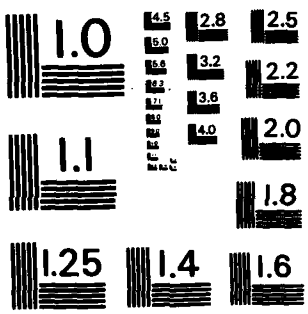

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TECHNICAL REPORT RD-83-11

A STUDY TO DETERMINE THE ACCURACY OF TWO COMPUTER PROGRAMS IN PREDICTING HINGE MOMENTS FOR ALL MOVABLE TAIL FINS ON MISSILE BODIES

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May 1983

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The preliminary design of a guided missile with movable control surfaces requires an in-depth study of the aerodynamic loading experienced by these surfaces. (author)

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LIST OF SYMBOLS

CHT - Hinge moment coefficient based on exposed fine area and root chord. Moments referenced about leading edge root chord.

CNT - Normal force coefficient based on fin plan-form area.

CP C_r - Center of pressure location in percent root chord.

I. INTRODUCTION

The preliminary design of a guided missile with moveable control surfaces requires an in-depth study of the aerodynamic loading experienced by these surfaces. Some important details such as sizing fin actuators or predicting the maximum fin balance load expected during a wind tunnel test requires the ability to predict aerodynamic loading within a reasonable amount of accuracy.

A study was made to examine the accuracy of programs AERODSN, developed at MICOM{1}, and MISSILE2A, developed by Nielsen Engineering and Research {2}, in predicting hinge moment of all moveable fins attached to missile bodies. Hinge moment prediction includes determining of chordwise center of pressure location and normal force magnitude. Missile configurations from the HIALFA data base were used to compare the two codes. By comparing theoretical results with experimental tests and effort was made to determine an expected range of accuracy for each of the two programs.

All moveable tail fins with aspect ratios of 0.5, 1.0 and 2.0 and taper ratios of 0.0, 0.5 and 1.0 were compared to wind tunnel data at Mach numbers from 0.8 to 3.01. Normal force and hinge moment coefficients were calculated using AERODSN and MISSILE2A computer programs. AERODSN is based on slender body theory and is applicable for small angles of attack.

MISSILE2A utilizes a data base augmented by analysis and is applicable over a MACH number range of 0.8 to 3.0, and angles of attack from 0 to 45 degrees. Center of pressure location in percent root chord is calculated using normal force and hinge moment coefficient.

II. PROGRAM DESCRIPTION

AERODSN{1} and MISSILE2A{2} are the two programs used for calculating hinge moments for a given range of fin geometries. Presented in this section is a brief description of the methods used by each program to calculate fin forces.

AERODSN is based on slender body theory and is limited to small angles of attack. Data from Design Charts (NACA 1307),{3} are stored in table lookup for calculating tail body interference factor. The charts are applicable for fins with taper ratios of 0.0 to 1.0 and MACH numbers from subsonic to supersonic. Fin alone normal force coefficient at zero angle of attack is taken from Design Charts presented in Reference {1}. These data sheets are parametric design charts obtained from various sources. Those for subsonic flow are obtained by applying the similarity laws of linearized theory to Weissingers' method. Those for supersonic flow are based on linearized supersonic lifting surface theory. Slender wing theory is used to give the slop of the lift curve at MACH 1. The theories are based on inviscid flow and apply to thin fins at small angles of attack.

MISSILE2A{2} utilizes a data base augmented by rational analysis and is applicable over a MACH range of 0.8 to 3.0, and angles of attack from 0 to 45 degrees. Fin loads are calculated utilizing a correlation method that is based on a nonlinear equivalent angle of attack concept. This method relates the forces experienced by placing two opposite fins together in the absence of the body. The equivalent angle of attack method is based on the following assumption: if a fin on a body has the same normal force coefficient (based on planform area) as a wing alone composed of two of the same fins joined together at their root chords, then the other force and moment coefficients of the fin and the wing alone are the same including the nonlinearities{4}. A number of interference factors are considered in determining equivalent angle of attack: (1) upwash due to angle of attack, (2) a change in loading due to a coupling between angles of attack and sideslip, (3) panel interference due to fin deflection and (4) induced changes in normal force on the fin due to vortices present in the flow field. Once the results of all these effects on the fin equivalent angle of attack have been determined and combined in a nonlinear fashion, the equivalent angle of attack is known. The normal force coefficient is then found from experimental wing alone data. By this technique, nonlinear characteristics of the wing alone are used in the predictive method.

III. ANALYSIS

Range of Geometry and Test Conditions – To determine a range of accuracy, AERODSN and MISSILE2A are compared to wind tunnel data stored on MICOM's aerodynamic data base. These data were obtained through a series of wind tunnel tests, conducted by MICOM, for cruciform tail fins with aspect ratios of 0.5, 1.0, and 2.0 and taper ratios of 0.0, 0.5, and 1.0 mounted on cylinderical bodies. This body fin combination is oriented in the plus configuration with zero tail deflections. Angles of attack range from 0 to 20 degrees. Center of pressure location, fin normal force and hinge moment coefficients are calculated for these configurations at MACH numbers of 0.8, [illegible], 1.75 and 3.01 by AERODSN and MISSILE2A, stored in a file, and compared with the wind tunnel data. Fin hinge moment coefficient is based on fin root chord and exposed fin plan form area and is referenced about the leading edge root chord. Normal force coefficient is based on fin planform area. Figures 1A through 3C are grouped according to aspect ratio. Figures 1A, 2A, and 3A show hinge moment coefficient, normal force coefficient and XCP/CR with varing taper ratios and Mach numbers. The same pattern follows for figure groups B and C. AERODSN, MISSILE2A and EXPERIMENT are written on the plots to indicate the appropiate curve.

IV. SUMMARY

NORMAL FORCE ACCURACY

MISSILE2A predicted normal force coefficient within 20% for 70% of the cases tested. This program proved to be reasonably accurate up to an angle of attack of 16 degrees. Figures 1A through 3C show normal force coefficient tends to become less accurate as aspect ratio decreases. Also, it can be seen that MISSILE2A underpredicts normal force coefficient for 95% of the cases.

AERODSN does not predict normal force coefficient as accurate as MISSILE2A at high angles of attack, however, AERODSN is good within 10% at small angles of attack up to about 4 degrees. Since AERODSN is based on slender body theory it is noe expected to accurate at high angles of attack. Taper ratio and aspect ratio do not seem to have an effect on initial slope accuracy.

XCP/CR ACCURACY

MISSILE2A predicted XCP/CR within 10% for 80% of the cases. The rest were within 20%. As aspect ratio increases XCP/CR seems to move aft of experiment. Taper ratio has no obvious effect.

AERODSN predicts XCP/CR within 10% for 70% of the cases.

HINGE MOMENT ACCURACY

For hinge moment prediction one program appears to be as accurate as the other. There seems to be no particular configuration or Mach number in which either program is more accurate. The combination of CN and XCP produce a reasonably accurate estimation of hinge moment coefficient at angles of attack to 20 degrees.

IV. CONCLUSIONS

Both MISSILE2A and AERODSN predict hinge moment for all moveable tail fins at Mach numbers from 0.8 to 3.01, taper ratios of 0.0 to 1.0 and aspect ratios of 0.5 to 2.0 mounted on missile bodies, with reasonable accuracy. It is recommended to use MISSILE2A for obtaining normal force coefficient at high angles of attack, however, for obtaining initial slopes, AERODSN is sufficient.

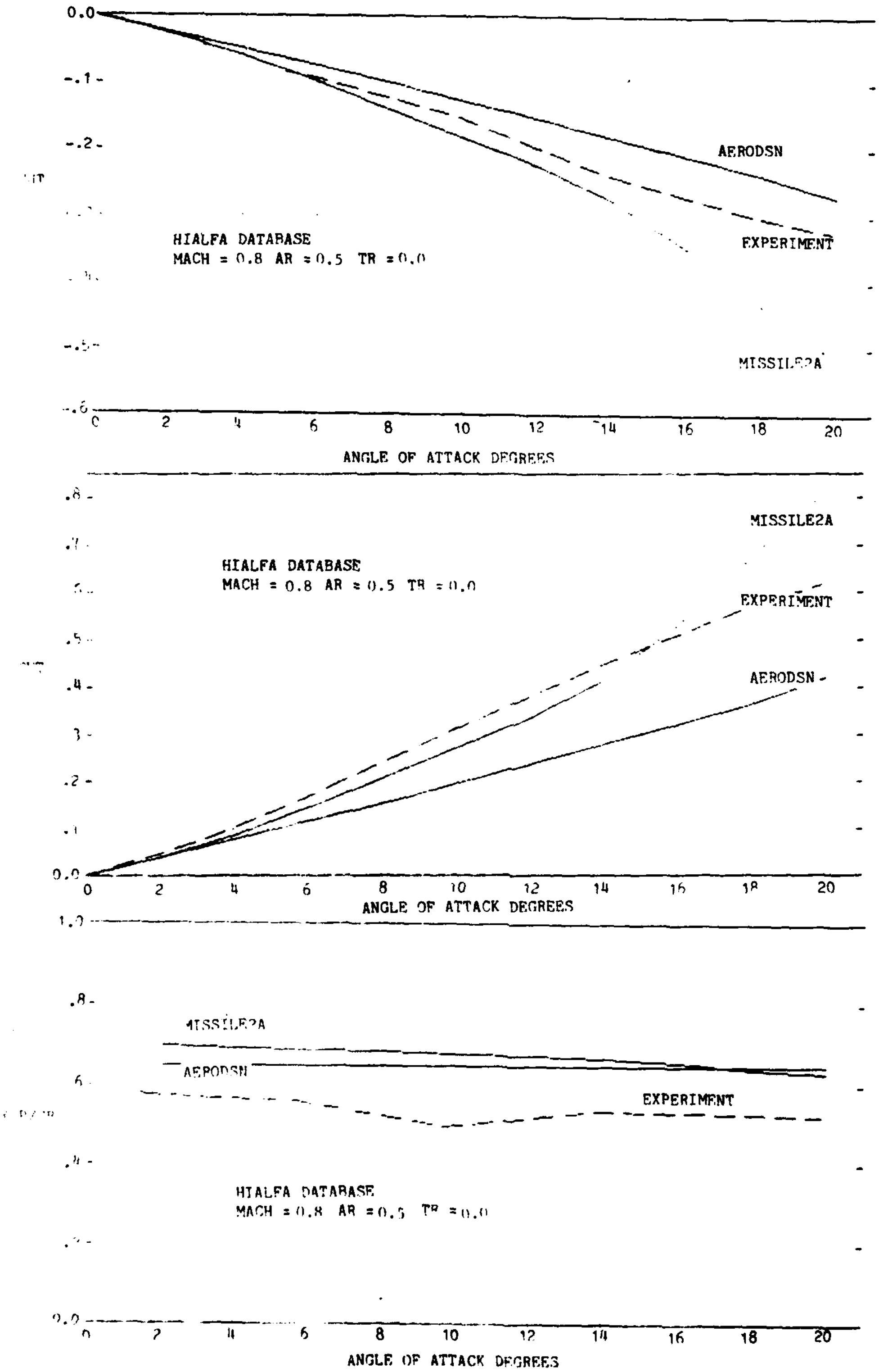


Figure 1A. Taper ratio = 0.0 MACH = 0.8 Aspect ratio = 0.5.

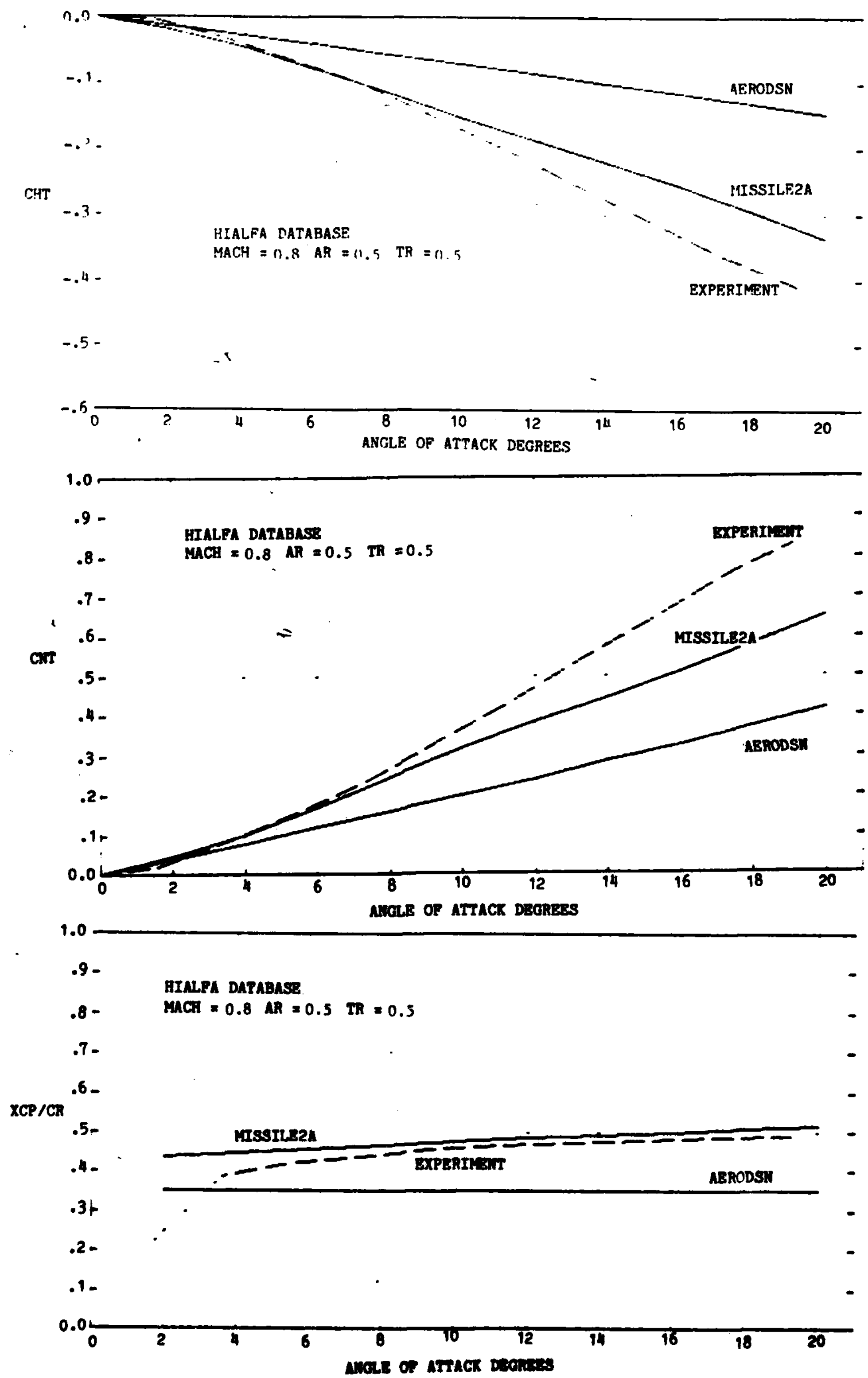


Figure 2A. Taper ratio = 0.5 MACH = 0.8 Aspect ratio = 0.5.

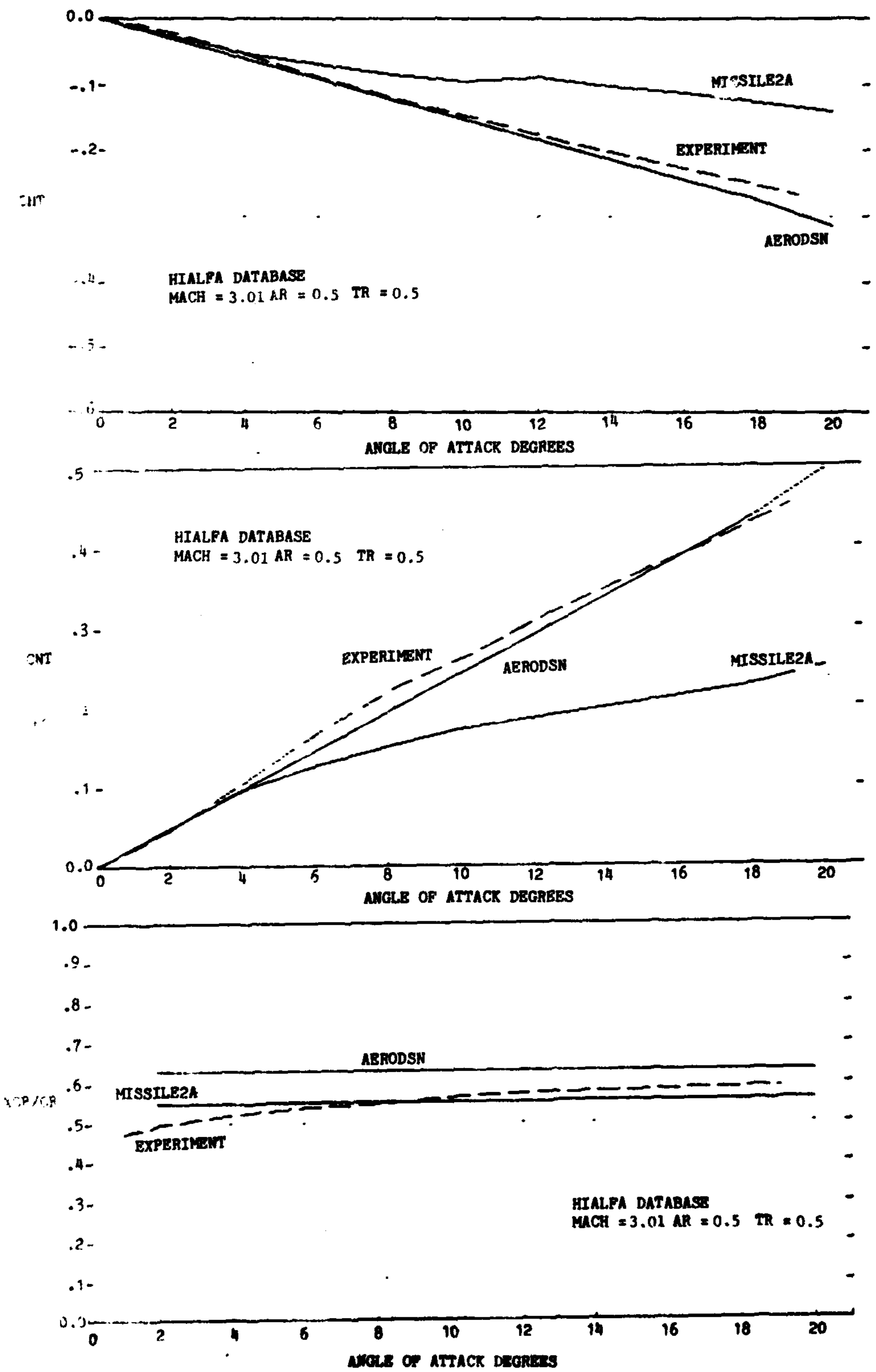


Figure 2A. (Con't) Taper ratio = 0.5 MACH = 3.01 Aspect ratio = 0.5.

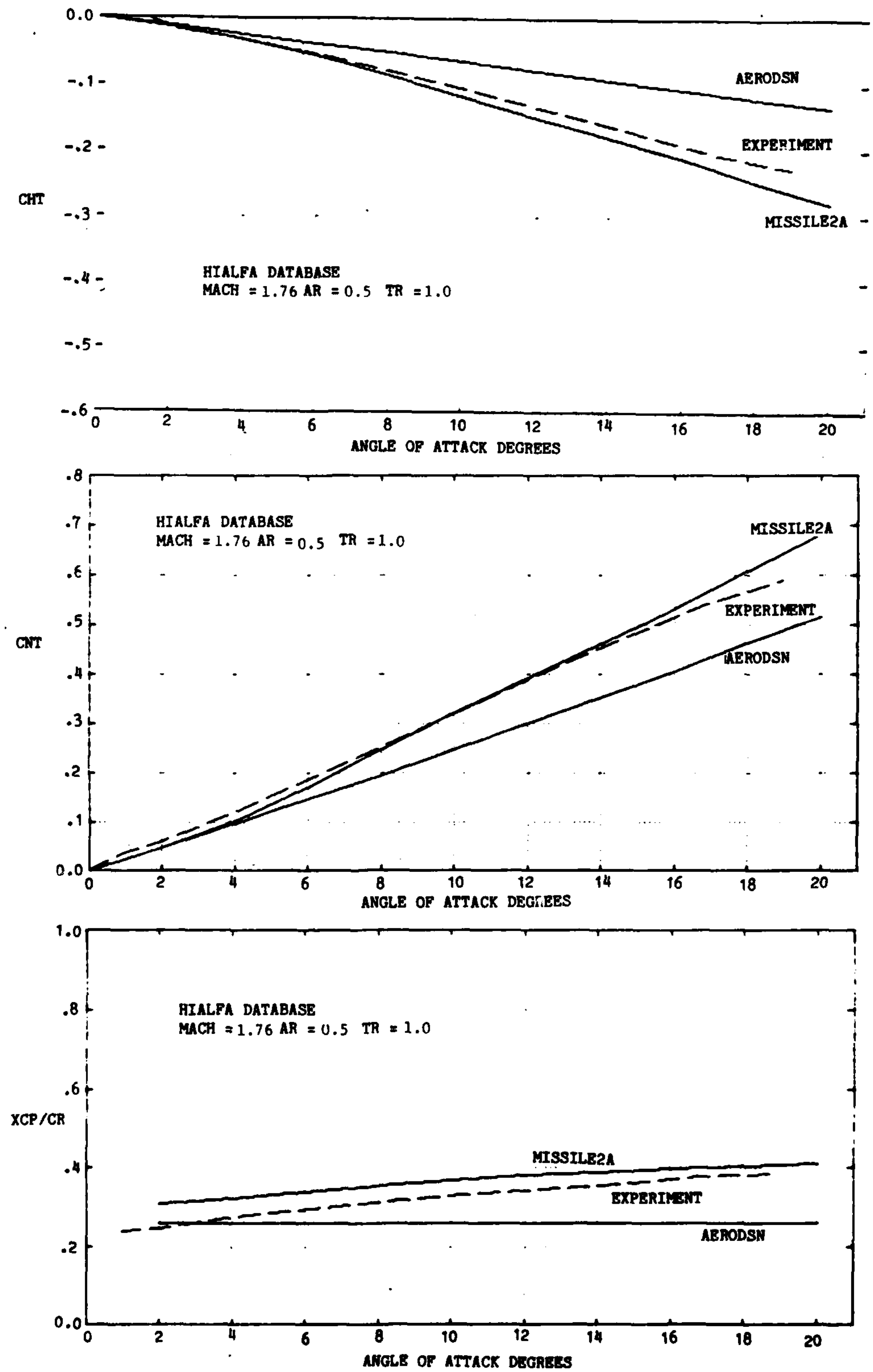


Figure 3A. Taper ratio = 1.0 MACH = 1.76 Aspect ratio = 0.5.

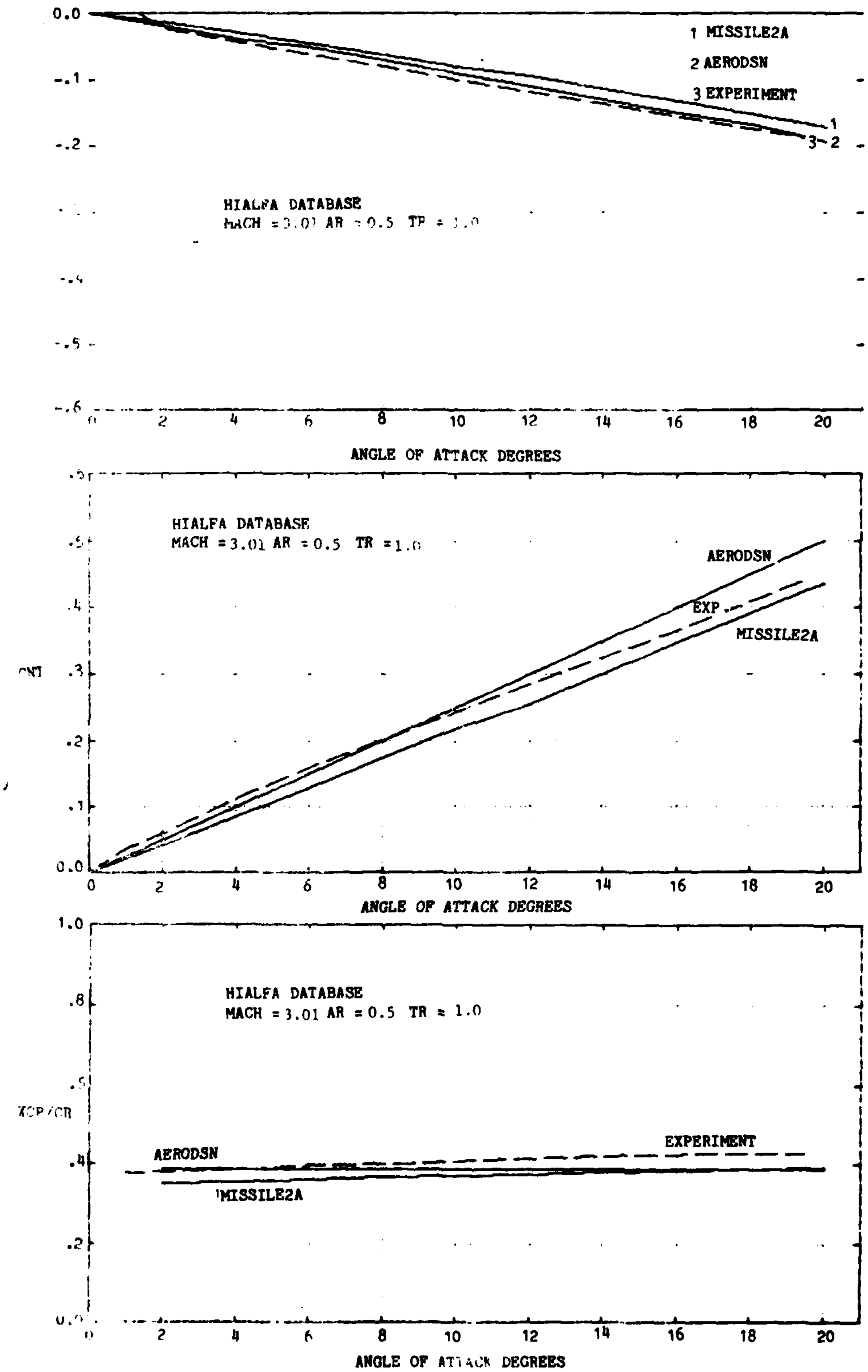


Figure 3A. (Con't) Taper ratio = 1.0 MACH = 3.01 Aspect ratio = 0.5.

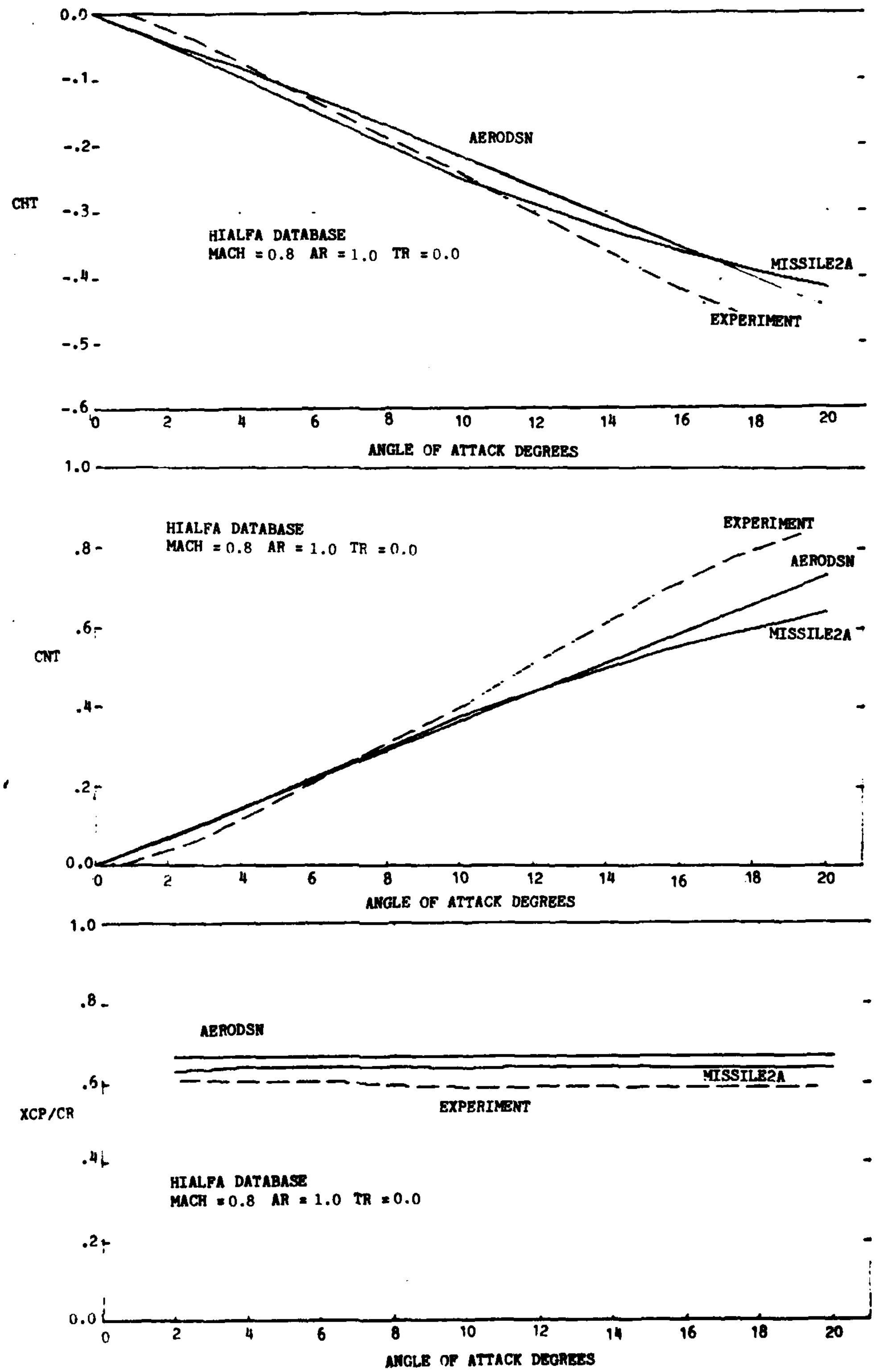
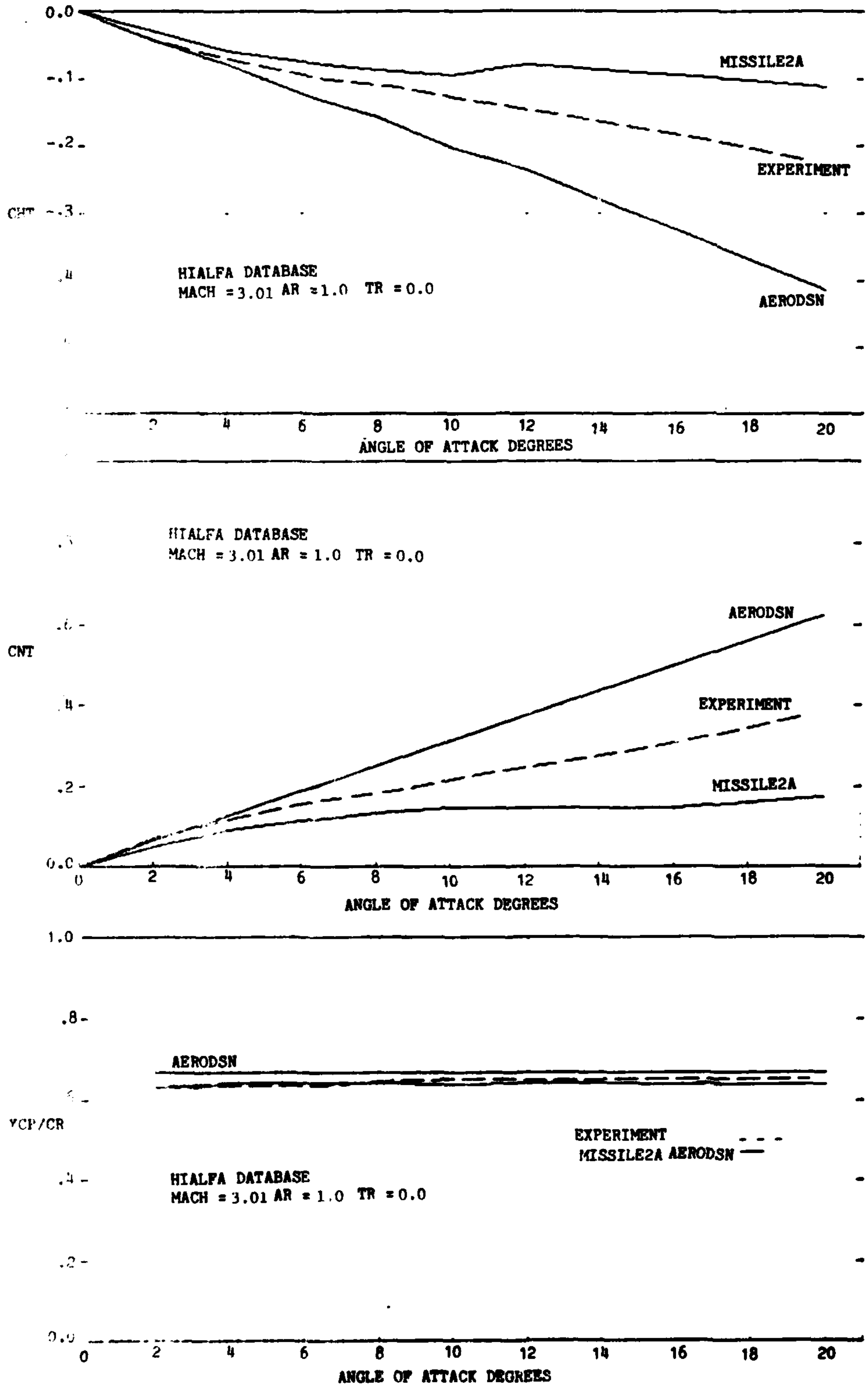


Figure 1B. Taper ratio - 0.0 MACH = 0.8 Aspect ratio = 1.0.



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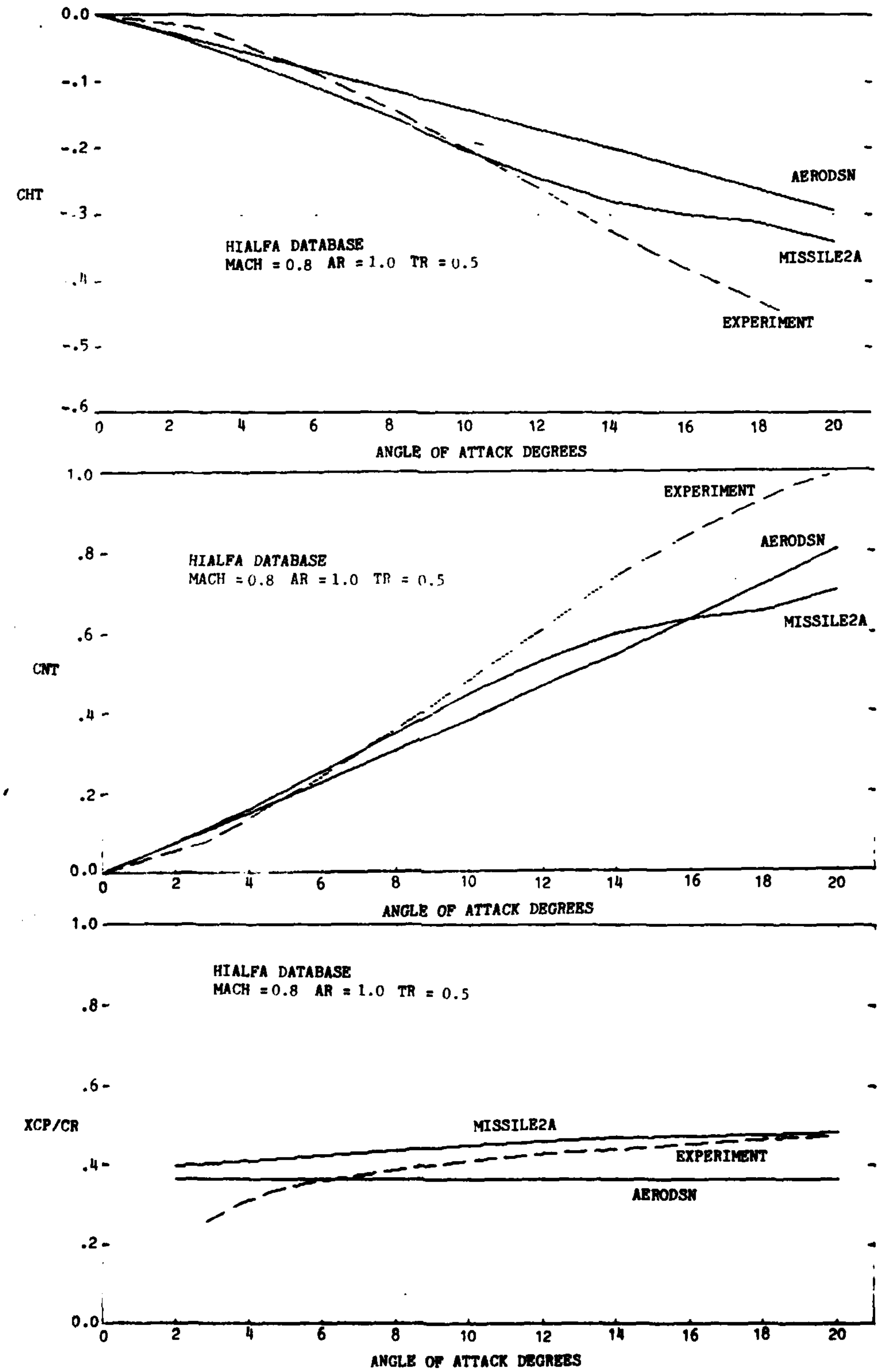
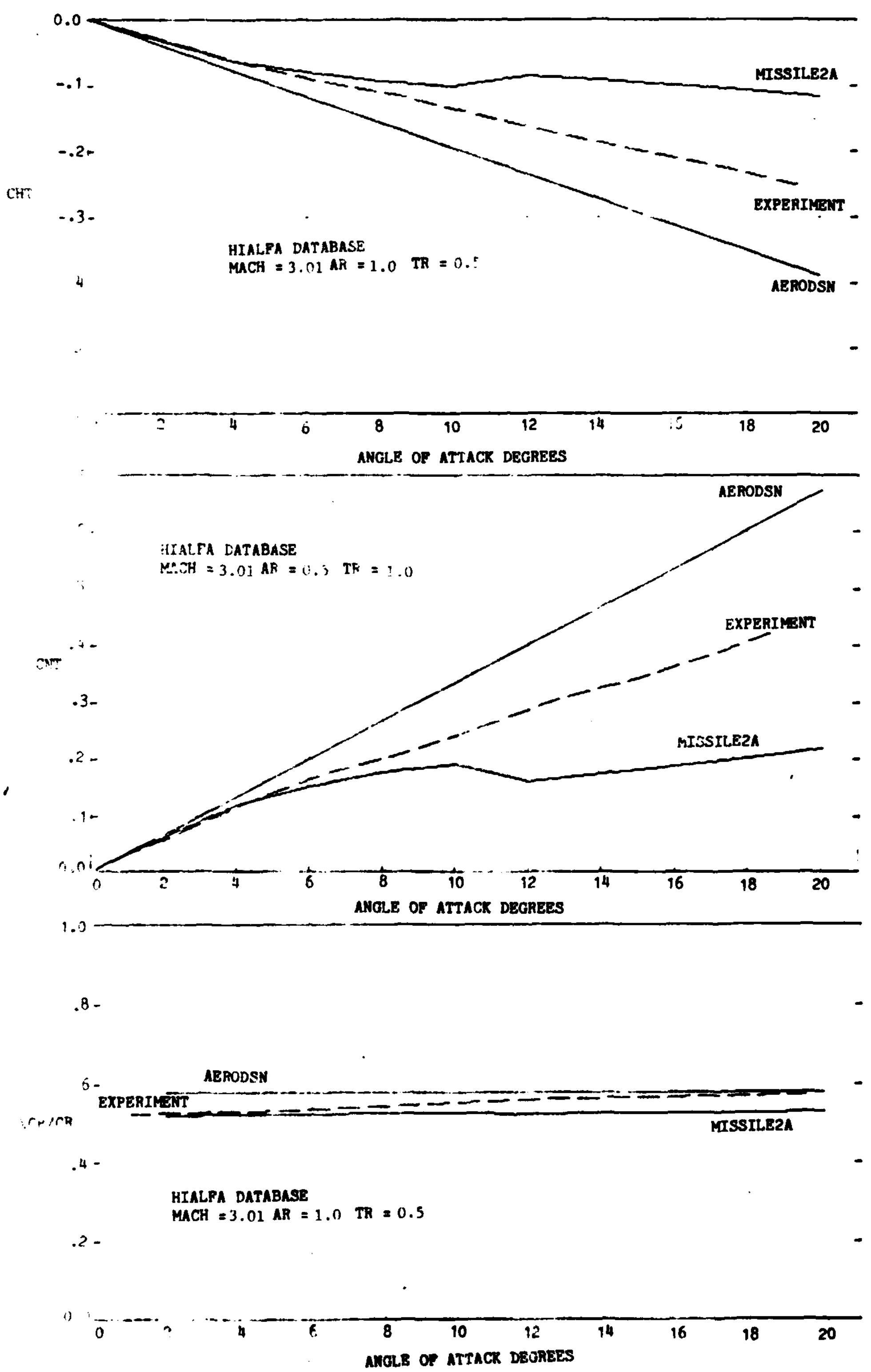


Figure 2B. Taper ratio = 0.5 MACH = 0.8 Aspect ratio = 1.0.



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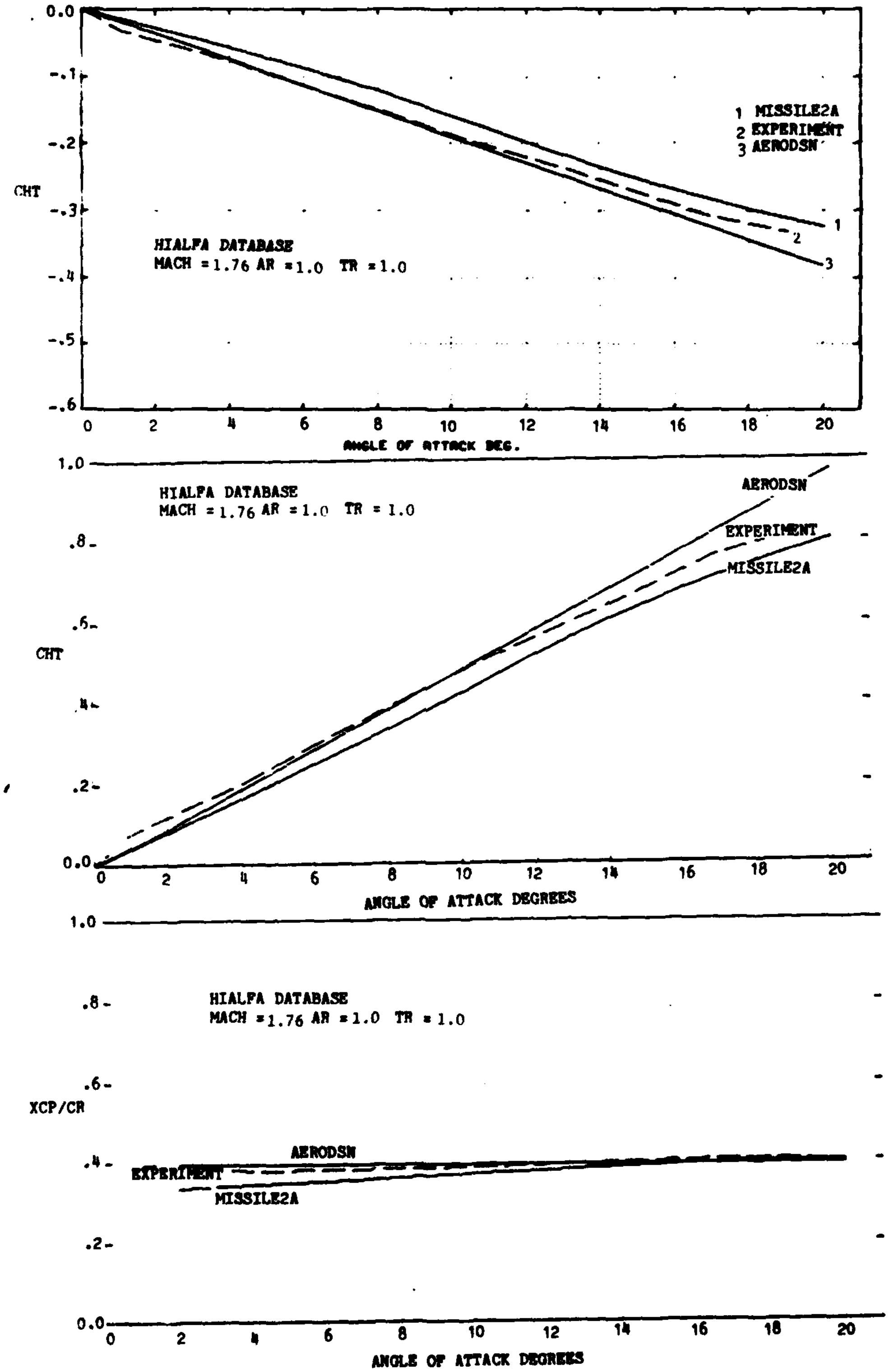

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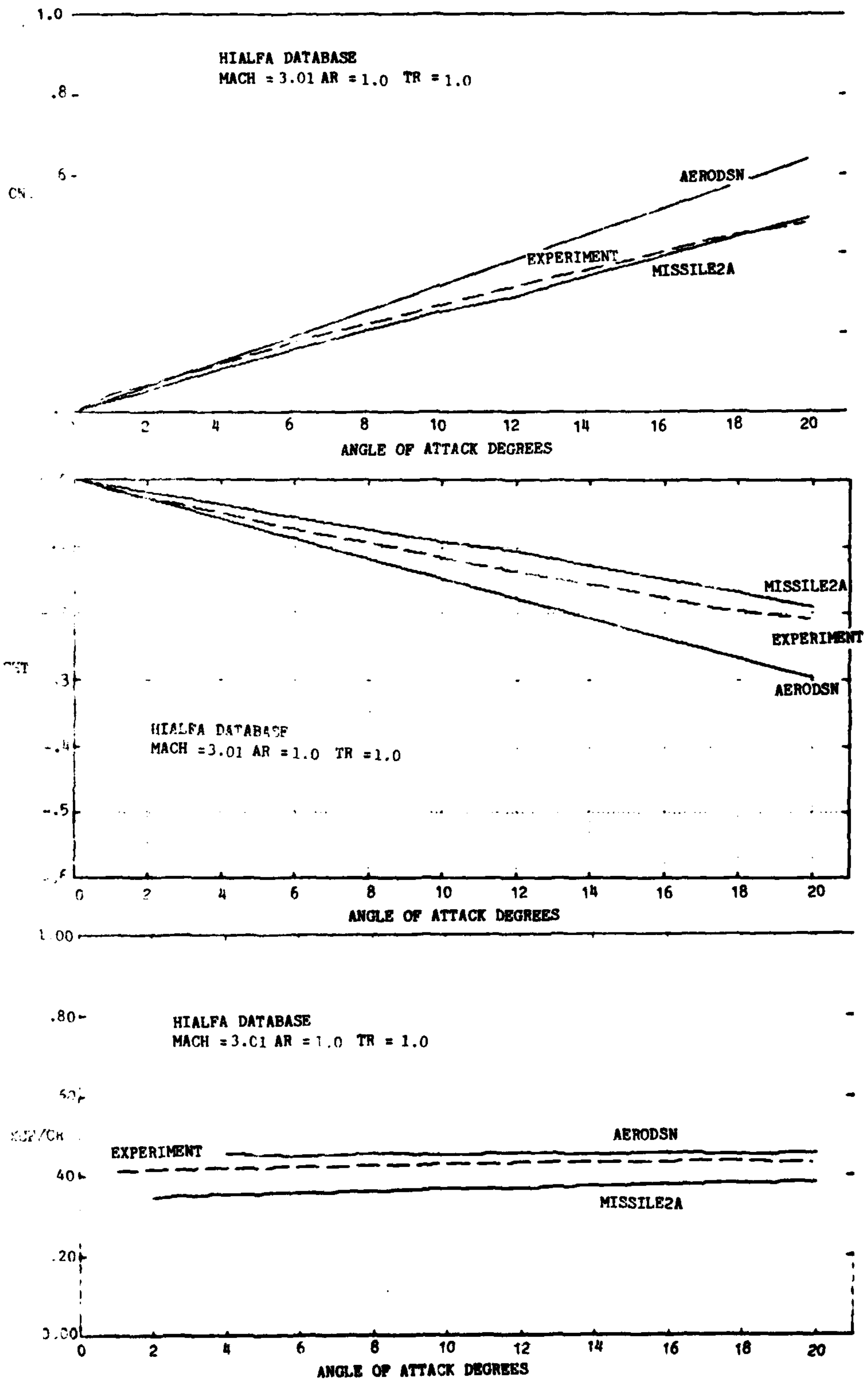

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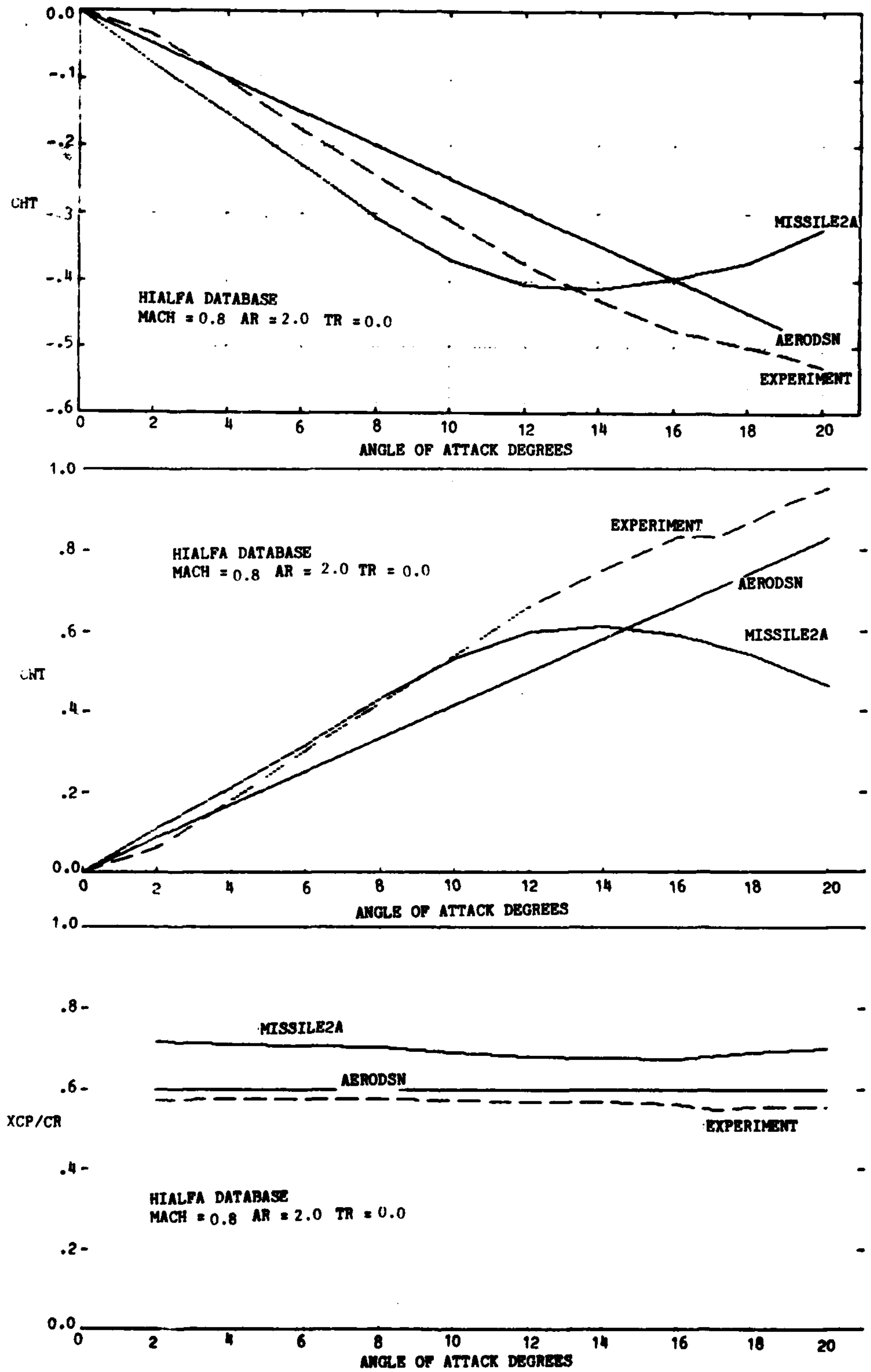


Figure 1C. Taper ratio = 0.0 MACH = 0.8 Aspect ratio = 2.0.

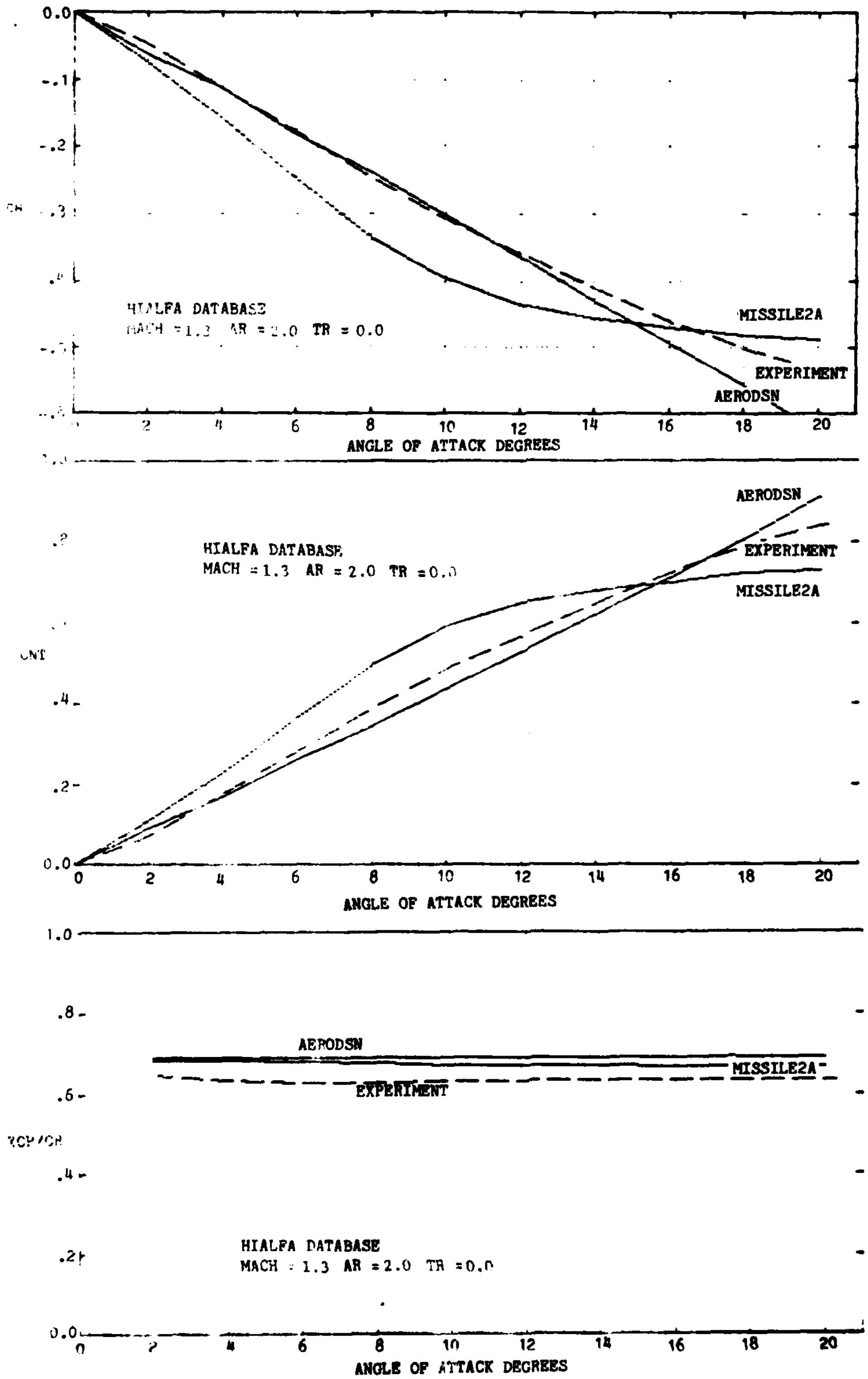
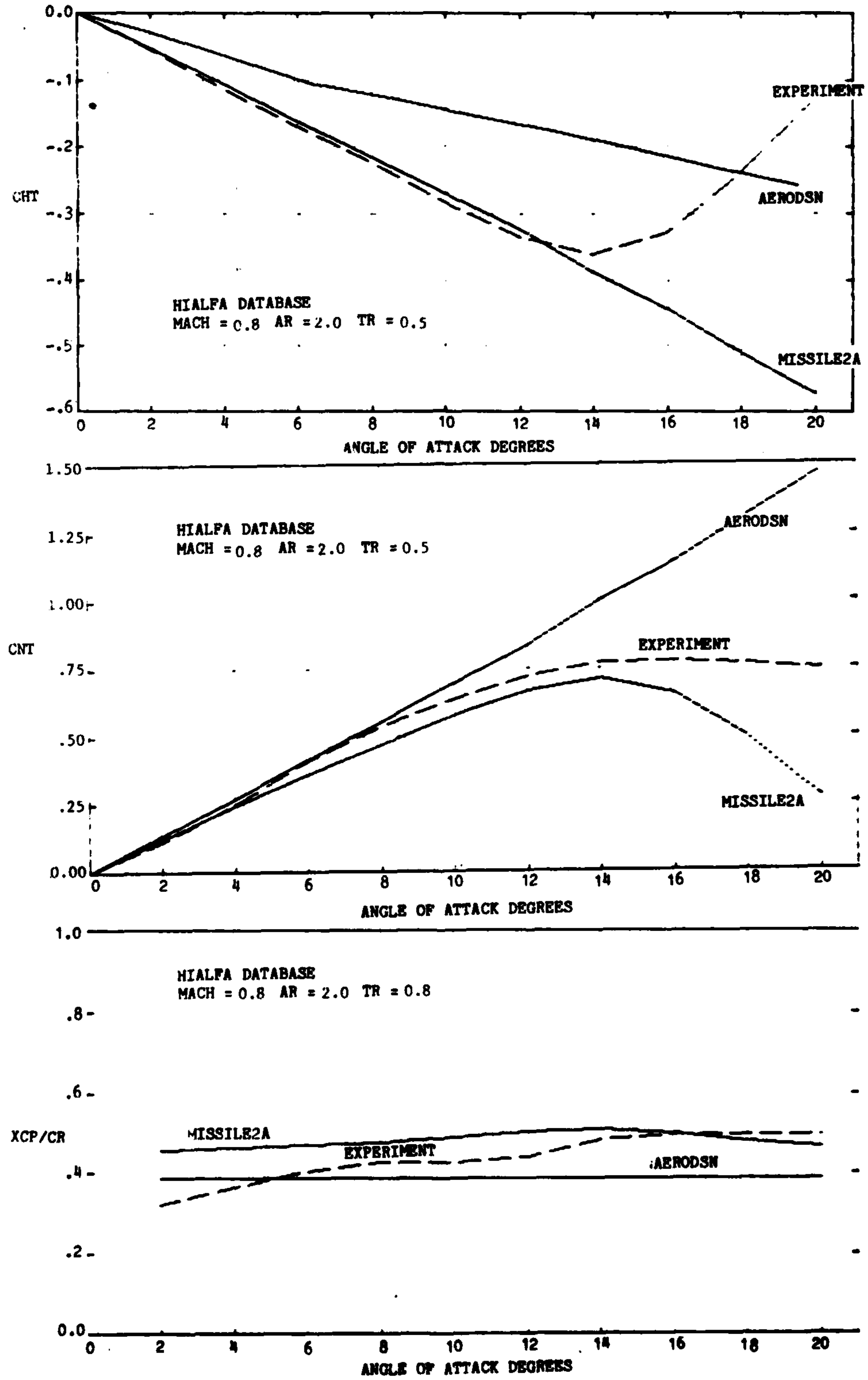


Figure 1C. (Con't) Taper ratio = 0.0 MACH = 1.3 Aspect ratio 2.0.



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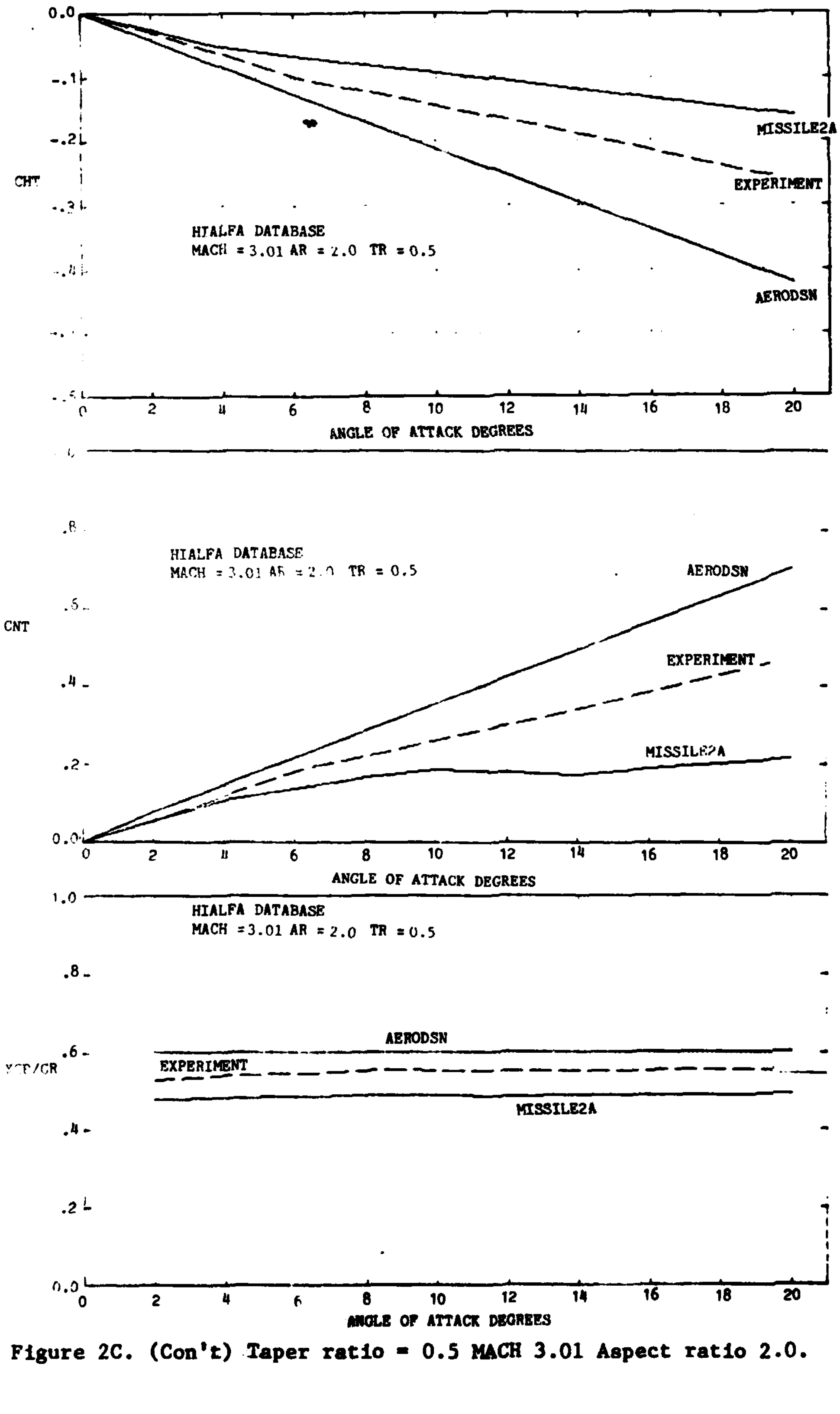

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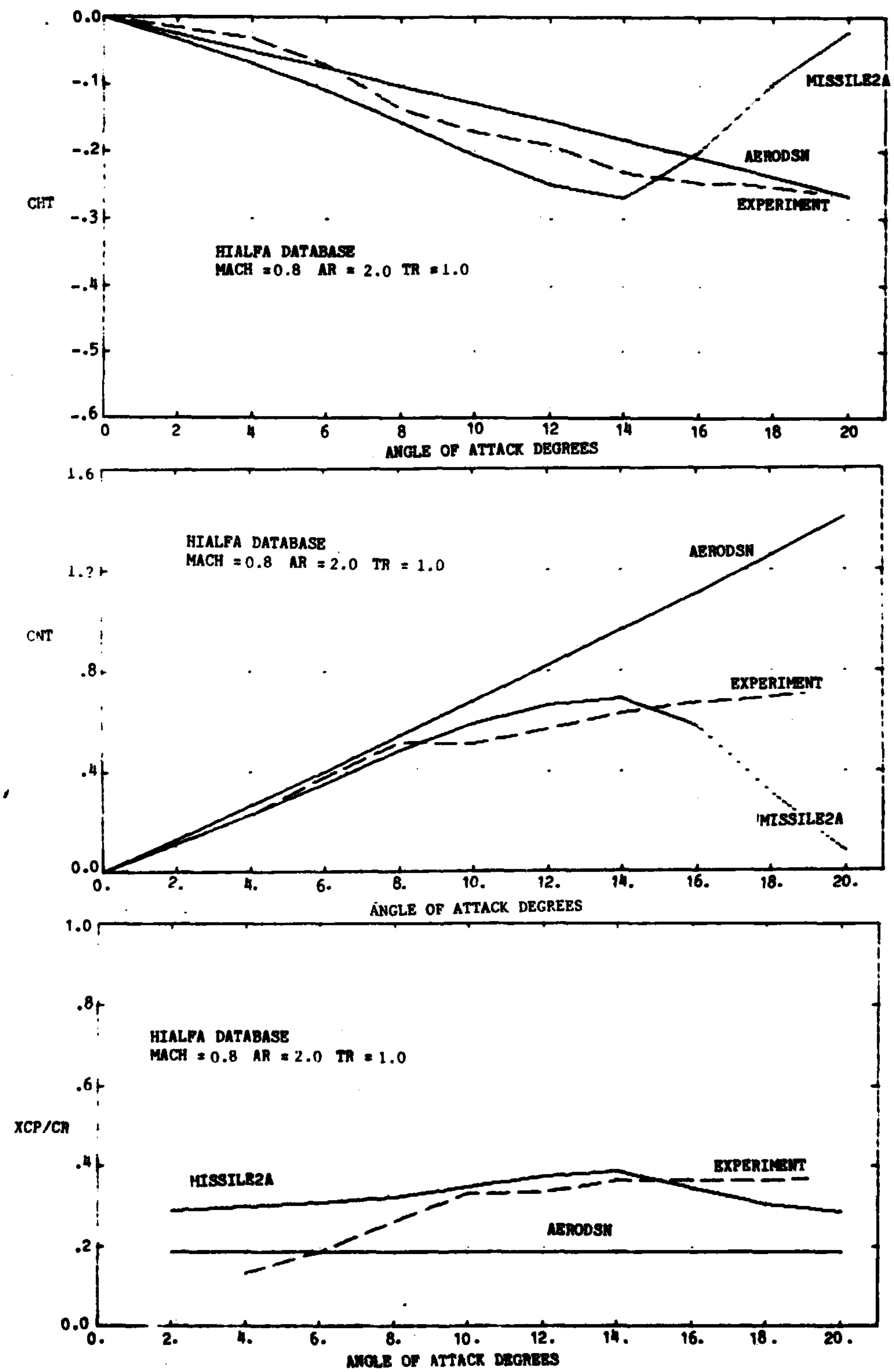

Figure 3C. Taper ratio = 1.0 MACH = 0.8 Aspect ratio 2.0.

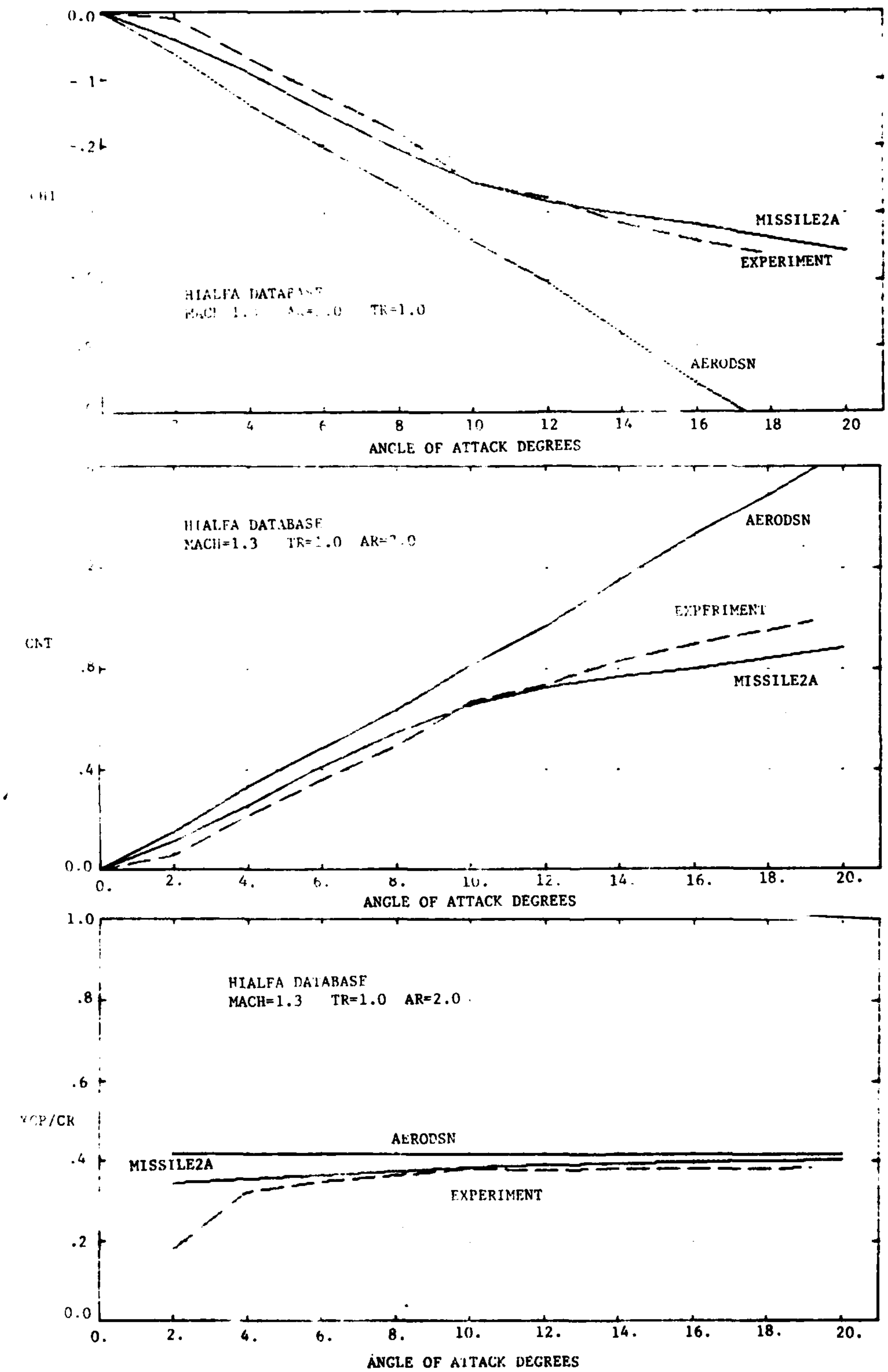

Figure 3C. (Con't) Taper ratio =1.0 MACH = 1.3 Aspect ratio = 2.0.

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